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NAME AND LOCATION: Alan Strahler, Boston University

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ABSTRACT -- KEY POINTS

Further tests with the semiempirical models confirm their suitability for fitting surface BRDF to MODIS and MISR measurements. They fit a series of 11 land cover types with high accuracy. Further, the best-fitting models are those for which the physical approximations match the character of the cover. The fitting algorithm is trivial compared to fitting a full physical model through forward iteration. BRDF/Albedo code using semiempirical models was provided to the MODOS SDST.

Thresholding methods for land cover classification based on composited AVHRR surface temperature and NDVI did not provide good pixel-by-pixel classification accuracies in a series of trials with a California land cover database. A fuzzy ARTMAP artificial neural network classifier performed well on AVHRR GAC data for Africa. Thresholding code was delivered to the MODIS SDST.

TASK PROGRESS

BRDF/Albedo Product

Model Development

During the reporting period, we continued our development of semiempirical models of bidirectional reflectance. As noted in the prior report, these models are physically based yet may be easily fit to empirical data. A major breakthrough was the development of a new and very simple approach to model fitting. Since the semiempirical models fit bidirectional reflectance as a linear sum of three functions that are controlled by illumination and viewing geometry, least squares fitting requires only the inversion of a three by three matrix. This allows a large number of semiempirical models (e.g., twenty) to any set of directional reflectance measurements so that the best fitting model can be easily determined.

Model Validation

Using bidirectional reflectance data for eleven land cover types as provided by Dan Kimes of Goddard Space Flight Center, we validated the semiempirical models to provide very good fits. Further, in many cases the best fitting semiempirical model was also the model for which the physical approximations were best suited to the land cover type.

In another validation effort, we fit the hybrid BRDF model to pyranometer measurements of a downwelling irradiance in a sparse conifer canopy with snow ground cover. The results showed a very good fitting to diffuse and multiply-scattered radiation, which confirmed the appropriateness of the model's approach. This work was conducted in connection with the BOREAS experiment.

As yet another part of our model validation effort, the principal investigator and Dr. Wanner traveled to China in July, acquiring BRDF measurements in the Jinguetan Laboratory of the Chinese Academy of Science, Changchun, China. The data have not yet been analyzed, due to the press of other responsibilities. On the same trip, we also visited an agricultural test site in east central China, where BRDF measurements will be made outdoors on a number of crops and land covers.

Software and Algorithm Development

Considerable effort was expended during the reporting period on software and algorithm development. In a collaboration with University College, London, we developed and released a software package called AMBRALS (Algorithm for MODIS Bidirectional Reflectance Anisotropy of the Land Surface). This program package includes a suite of physical and semiempirical BRDF and albedo models that can be exercised in a forward direction or inverted and fit to observations. The code is written in C and is now well documented, and is currently in version 1.3.

In a related coding effort, we provided a code delivery to the SDST of the semiempirical inversion code in a version suitable for pixel by pixel inversion of MODIS and MISR measurements. Documentation was also provided.

Atmospheric Correction-BRDF Effects

A problem arises in the atmospheric correction of MODIS measurements when isotropic reflectance is assumed. For high accuracy, surface reflectances must be obtained using a BRDF model. However, the BRDF model may not be fitted without accurate measurements of directional reflectance. During the reporting period, we worked closely with Eric Vermote to resolve the circularity. Our approach will be a single loop extraction procedure in which isotropic reflectances are used to fit a BRDF, the BRDF is used to rederive reflectances and a revised set of reflectances and new BRDF are fitted using the iteration. More details are provided in the revised BRDF/Albedo product ATBD, which is forthcoming.

Albedo Sensitivity Studies

Toward the close of the reporting period, we began a series of studies on the sensitivity of albedo obtained by hemispherical integration of semiempirical BRDFs to the viewing and illumination constraints imposed by the geometry of MISR and MODIS viewing and

the orbital characteristics of the AM platform. Preliminary results suggest that BRDF integration can be inaccurate under some circumstances.

Land Cover/Land-Cover Change

During this reporting period, our work focused primarily on algorithm development for land cover classification. We continued our trials of the NDVI and surface temperature thresholding methods proposed by Running and Nemani, as applied to the Plumas National Forest in the California Sierra Nevada, and to the entire state of California as well. Our results showed that this approach was unable to provide reasonable accuracies at the 1 km pixel level. As a result, we turned more strongly to the development of neural network approaches to land cover classification. In this work, we found neural network to provide significantly higher accuracies.

Algorithm Development

As required by MODIS management, we delivered software for the land cover product, providing C code that implements a threshold-style classifier on multitemporal image data. The code was delivered to the MODIS SDST.

Land Cover ATBD

As required by the EOS Project Science office, we revised and resubmitted the Land Cover/Land-cover Change Algorithm Theoretical Basis Document (ATBD). The revision was an extensive one, requiring many weeks of work. Also submitted in a separate communication was a response to the comments of both the ATBD review panel and the mail reviewers.

ANTICIPATED ACTIVITIES DURING THE NEXT QUARTER

BRDF/Albedo Product

Our primary activity during the next quarter for the BRDF/Albedo product will be to complete our revision of the ATBD, which is presently overdue. In addition to that activity, we will continue refining the application of the semiempirical models, their validation, and their use to calculate albedo in realistic MODIS-MISR sensing scenarios.

Land Cover/Land-cover Change Product

During the next quarter, we will continue algorithm development for land cover classification using neural network classifiers. This work will require assembling single-year multi-date TM images for test sites for which land cover information is available. Such data sets allow us to explore the spectral, temporal, and spatial information content that will characterize MODIS data. In land-cover change activities, we will continue our liaison with Eric

Lambin at the European Economic Community's Joint Research Center. Activities there focus on land-cover change as inferred from a ten year record of African AVHRR observations.

PROBLEMS/CORRECTIVE ACTIONS

During this reporting period, we did not encounter any significant problems requiring corrective actions beyond the everyday problems that occur in research and algorithm development.

PUBLICATIONS

Attached below is an updated list of publications derived with full or partial support under this contract. Items marked with an asterisk are new publications that are being submitted separately in hardcopy to the project management.

MASTER MODIS PUBLICATION LIST

January 1, 1995

Submitted

Moody, A., S. Gopal, and A. H. Strahler, 1995, Sensitivity of neural network outputs to subpixel land-cover mixtures in coarse-resolution satellite data, submitted to Remote Sens. Environ. (July 94).

Strahler, A. H., 1995, Vegetation canopy reflectance modeling -- Recent developments and remote sensing perspectives, submitted for journal publication through the Proceedings of the Sixth International Symposium on Physical Measurements and Signatures in Remote Sensing (Mar 94).

In Press

Moody, A. and Woodcock, C. E., 1995, The influence of the spatial characteristics of landscapes on land-cover mapping using remote sensing, Landscape Ecology, in press.

Moody, A. and Woodcock, C. E., 1995, Calibration-based methods for correcting coarse resolution estimates of land-cover proportions, Proc. Spring Meeting, 1995, Amer. Soc. Photogramm. and Remote Sens., in press.

Borak, J., Fisher, P., Strahler, A., and Moody, A., 1995, Local-scale evaluation of a technique for land-cover classification based on composited NDVI data, Proc. Spring Meeting, 1995, Amer. Soc. Photogramm. and Remote Sens., in press.

Woodcock, C. E., J. B. Collins, and D. L. B. Jupp, 1995, Scaling remote sensing models, in Scaling Up, P. van Gardingen, G. Foody, and P. Curran (eds.), Society of Experimental Biology, Cambridge University Press, in press.

Li, X., A. H. Strahler, and C. E. Woodcock, 1995, A hybrid geometric optical-radiative transfer approach for modeling albedo and directional reflectance of discontinuous canopies, IEEE Trans. Geosci. and Remote Sens., in press (July 94).

Liang, S. and A. H. Strahler, 1995, An analytic radiative transfer model for a coupled atmosphere and leaf canopy, J. Geophys. Res., in press (Nov 94).

Li, X. A. H. Strahler, and C. E. Woodcock, 1994, Hybrid geometric-optical radiative-transfer model for the directional reflectance of discontinuous vegetation canopies, Proc. European Symp. on Satellite Remote Sensing , Sept. 26-30, Rome, Italy (Eur. Optical Soc., SPIE-Int. Soc. for Optical Engr.), in press (Sept 94).

Schaaf, C. B. and A. H. Strahler, 1994, Using a geometric-optical model to calculate the bidirectional and hemispherical reflectance of forested slopes, Proc. European Symp. on Satellite Remote Sensing, Sept. 26-30, Rome, Italy (Eur. Optical Soc., SPIE-Int. Soc. for Optical Engr.), in press (Sept 94).

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Running, S., C. Justice, D. Hall, A. Huete, Y. Kaufmann, J-P. Muller, A. Strahler, V. Vanderbilt, Z-M. Wan, 1994, Terrestrial remote sensing science and algorithms planned for EOS/MODIS, Remote Sens. Environ., in press (Aug 93).

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